



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

CONTRIBUTIONS FROM THE JEFFERSON PHYSICAL
LABORATORY, HARVARD UNIVERSITY.

DISCHARGES OF ELECTRICITY THROUGH HYDROGEN.

By JOHN TROWBRIDGE.

Presented December 8, 1909. Received February 24, 1910.

1. Reflection of cathode rays	455
2. Striæ	456
3. The Doppler effect	462
4. Conclusions	462

1. REFLECTION OF CATHODE RAYS.

IN the course of this paper I shall refer to certain hydrodynamical analogies which the discharges of electricity through gases present; not with the conviction that in these discharges we have to deal with questions of flow alone. The complicated phenomena give large scope both to theories of flow and molecular theories: the hydrodynamical analogies are more striking in discharges through gases at comparatively high pressures; while molecular theories apply best in highly rarefied gases. There seems to be a certain continuity here similar to that between motions of matter in the liquid state and in the gaseous state, when such matter is subjected to forces which can produce movement or flow of the particles.

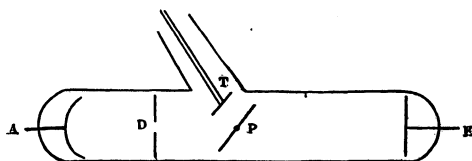


FIGURE 1.

The conditions of electrical discharges in a tube represented in Figure 1 remind one of the flow of a fluid interrupted by a plane lamina. A is a cathode, K an anode, D a diaphragm, P a plane lamina which can be moved about an axis perpendicular to the plane of the paper, Figure 1 being a plan of the discharge tube. P can also serve as an anode.

At the striæ stage the electrical conditions in the tube are very little modified by turning the lamina through small inclinations to the

line of discharge. The striæ remain practically unaffected in shape and position until the angle between the normal to the lamina and the axis of flow reaches 50° . This phenomenon is analogous to the case of a lamina subjected to the flow of a liquid (Lamb's Hydrodynamics, pages 94 and 111). It is also analogous to the conditions presented by the impact of wind on vanes.

By means of a side adjunct a thermo pile, T, was introduced in order to measure the heat excited by the reflection of the cathode rays passing through the diaphragm D and reflected from the lamina,

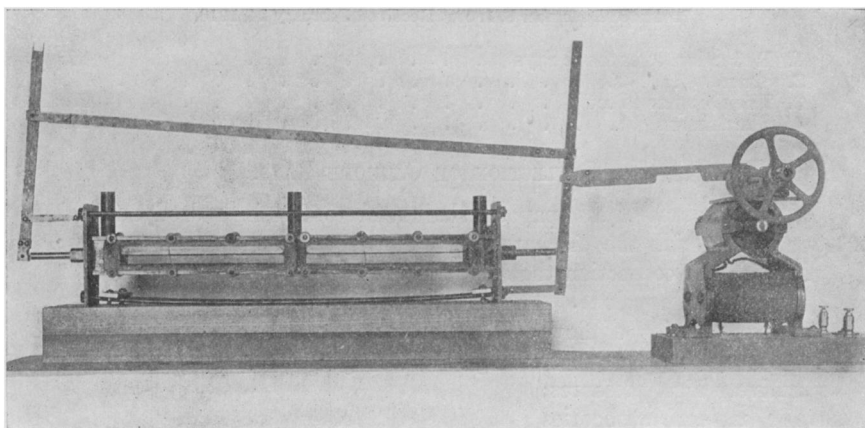


FIGURE 2.

when the latter was inclined to the axis of the cathode rays at varying angles. Here also there was an action similar to the reflection of a stream of liquid from the lamina, proceeding in the direction of the cathode rays. The angle between the normal to the lamina and the axis of flow or discharge could vary largely without affecting the amount of heat from the reflected cathode beam shown by the thermopile.

2. STRIÆ.

The striæ, or stratifications, in Geissler tubes constitute a very beautiful and mysterious phenomenon of the discharge of electricity through gases, and if one could follow the mechanism involved perfectly one could feel sure of having penetrated far into questions of the method of propagation of electricity. There seems no reason to doubt that the striæ are phenomena of ionization; but the regularity

of the striæ leads one to ask if this regularity could arise from some pulsation or rhythmical action, — the ionization being, so to speak, on top of such a rhythmical action. When the striæ are excited by a storage battery, they are perfectly steady, and when one is sure that there are no breaks in the circuit, a telephone introduced into the circuit is silent; moreover, self-induction included in the circuit does not affect the striæ.

Under certain conditions the current from a storage battery oscillates or pulsates, but such oscillations or pulsations do not seem to modify the appearance of the stratifications. If, on the other hand, there is a flow from the cathode which

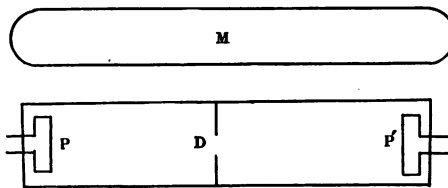


FIGURE 3.

pulsates at a different rate from a supposititious flow from the anode, one might expect striæ, or accumulation of ionic disturbances at regular intervals. An hydrodynamical analogy is afforded by the motion of two pistons moving against each other at different rates in a channel filled with water.

Figure 2 represents an apparatus by means of which two pistons driven in opposite directions by a motor cause waves in a trough filled with water.



FIGURE 4.

Figure 3 shows the arrangement, in plan, by means of which the ripples are studied. *M* is a mercury lamp of the Cooper Hewitt form. This is placed directly behind the trough containing the pistons. The surface of the water, totally reflecting the light, forms a dark line which under the motion of the pistons undulates in waves, which can be studied by instantaneous photography. *P* and *P'* are the pistons, and *D* is a diaphragm with a rectangular orifice. Figure 4 represents a case in which *P* moves twice as fast as *P'*. The waves are formed nearer the slower-moving piston.

All who have worked in the field of discharge of electricity through gases must recognize the suggestiveness of the theory of ionization by collision, especially in reference to striæ; but one who was ignorant of this theory, in seeing the action of the cathode rays in apparently

driving the striæ into the anode, might attribute this action to an actual repelling force arising from the cathode. When this supposititious force is diverted by a magnet, the striæ reappear and more current flows. One ignorant, too, of the many facts of ionization by collision might further suppose that heavier particles of slower motion might be held back by swifter particles issuing from the cathode. These views of a mind not biased by ionization theories would appear to be supported by the phenomena presented by the tube represented in Figure 5.

One branch of this tube is at right angles to the other branch. There are two anodes, A and A', and two perforated cathodes, K and K'. When a multiple circuit is formed by leading in the current to the two anodes and out by one

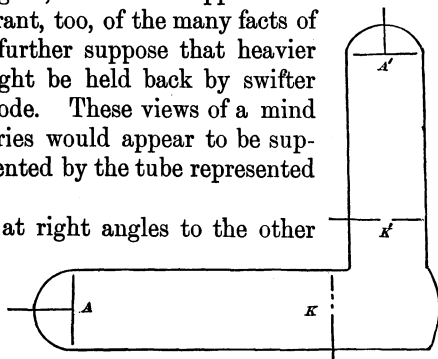


FIGURE 5.

cathode, K, striæ form in the branch A'K' after they disappear in the branch AK; and they persist in the branch A'K' when the branch AK appears to be nearly at the X-Ray stage. One looking at the branch A'K' would suppose that the rarefaction of the entire tube was low, and gazing at the branch AK would think it very high. The bend in the tube acts like a magnet in allowing the striæ to emerge from the anode A'; and it does this by enfeebling by reflection the effect of the cathode rays in the branch A'K'.

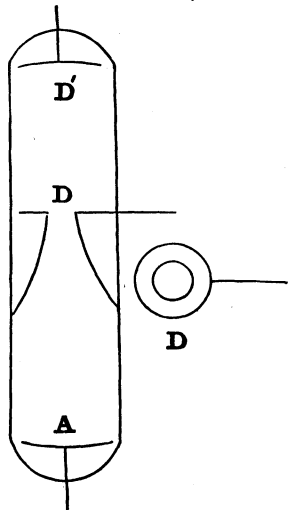


FIGURE 6.

The function of the cathode beam seems to be twofold: it forces back the striæ, and at higher exhaustions it ionizes the gas; for the current ceases to flow at high exhaustions when the cathode beam is strongly diverted by a magnet. These functions are illustrated by the phenomena in a tube represented in Figure 6.

Between the anode A and a cathode D the glass tube is constricted. The cathode D is a circular disc with an orifice a little larger than the glass orifice. The cathode rests upon the ground walls of this orifice, presenting no metallic surface toward the anode A. The cathode beam produces an orange fluorescence toward

D', and is marked in the direction toward A by a white beam which produces hardly a perceptible fluorescence. The latter beam does not come from the metallic surface of the cathode, but seems to come from the gas in the region DD'. At comparatively high exhaustions this latter portion of the cathode beam ceases to ionize the gas and the current ceases; the potential between A and D rises to the full potential of the battery—indicating an open circuit. When, however, D' is made the cathode, the current is immediately re-established and the cathode beam from D' ionizes the gas between D' and A. The tube acts as a rectifier; for when D is made the anode and A the cathode, a current passes; on reversal of the current, when at the same exhaustion, no current passes in the opposite direction.

It is interesting to observe the effect of a transverse magnetic field on the discharge in this tube when A is made a cathode and D an anode, and striæ appear in the portion DD'.

The magnetic field placed near A diverts the cathode beam and striæ advance in the portion DD'. While this field is still on, another transverse magnetic field placed near D' diverts the striæ independently of the action of the field at A. This indicates the well known fall of potential from striæ to striæ.

The rectification observed under proper conditions in the tube (Figure 6) suggests other forms of tubes by which rectification can be produced. Even with a straight cylindrical tube the current can be stopped at high exhaustions by touching the outside of the tube with the finger, thus diverting the cathode beam by electrostatic action; while it readily passes when the current is reversed. The phenomenon of rectification is shown in a practical way in the U-shaped tube represented in Figure 7. It is provided with two anodes, A and A', and two cathodes, D and D'. The cathodes have orifices at their centres. The two anodes are connected together, and the two cathodes—the tube forming a multiple circuit. A transverse magnetic field can be so placed near one cathode that no current will pass in the branch of the

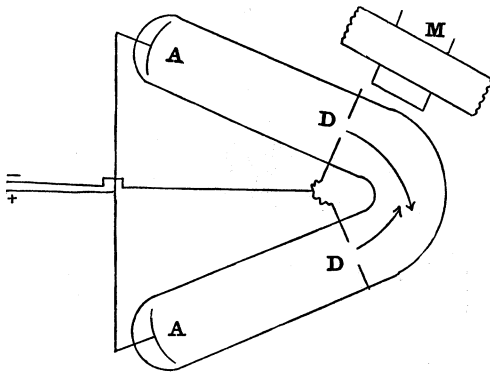


FIGURE 7.

tube of which it is a part, while the current passes freely in the other branch of the U tube. This form of tube rectifies an alternating current.

The apparent repelling or driving back action of the cathode beam on striæ is shown in a suggestive manner in a straight cylindrical tube when a diaphragm is inserted between the anode and the cathode. We will take for illustration one branch of the U-shaped tube (Figure

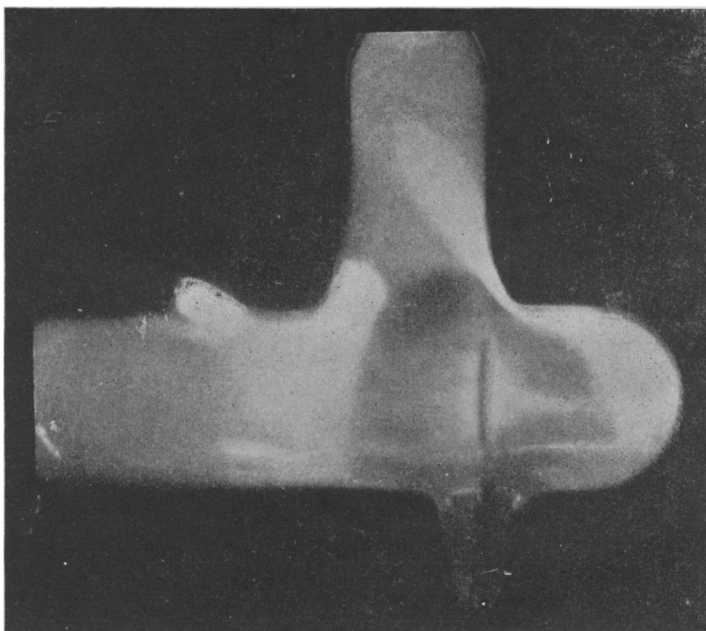


FIGURE 8.

7), and suppose that the current is led into the tube at A and out at D. A metallic diaphragm with a small hole at its centre is inserted in the tube about one third of the distance between A and D, measured from the anode A — the latter also having an orifice at its centre. The striæ are slowly driven back by the cathode rays as the exhaustion proceeds. At a definite stage of this exhaustion a striæ takes refuge behind the diaphragm nearer the anode, where it is protected from the driving back action of the cathode rays; finally at higher exhaustions this striæ is driven through the orifice in the anode and shelters itself behind the anode.

At a still higher state of rarefaction a stria issues from the orifice in the anode, and this also shelters itself behind the diaphragm on the side toward the anode. There are, thus, three definite stages of stratification in this form of tube. At a pressure of four centimetres fine striæ appear on the side of the orifice in the diaphragm opposite to the anode. These soon disappear with increasing rarefaction. At a pressure of approximately 3 mm. a large stria shelters itself behind the diaphragm. This fades into the orifice in the anode with diminishing pressure; and at a pressure of approximately .15 mm. a large stria wells up out of the orifice in the anode and takes a similar place near the diaphragm. When the state of canalstrahlen is reached, all striæ have been driven into the anode. Can we regard these strahlen as a stratification which cannot be driven back by the cathode rays? In this form of tube we find evidence of successive states of stratification which may depend upon positive rays of different velocity.

When we turn from our observation of stratification in the neighborhood of the cathode instead of in the neighborhood of the anode, we find that a stratification always takes place on the glass wall close to the entrance of the cathode, or to its sealing in place. It can be produced equally well by causing the cathode to approach the wall of the tube opposite to this sealing in place. Figure 8 represents the phenomenon in a tube with a dome-shaped chamber near the electrode. We seem to have two dissected striæ: one on the wall of the tube nearest to the cathode, which provides a beautiful light blue cathode beam thrown into the dome; and another stria on the opposite wall of the dome. The original cathode beam excites both positive and negative rays in these striæ. In considering these detached striæ it seems that the cathode rays in striking the glass walls can excite both positive and cathode rays.

When a spark gap is inserted in a circuit containing a discharge tube which is properly exhausted to the striæ stage, the latter apparently disappear—the light of the tube becomes more brilliant and fluorescence is generally manifested. This is also the case when a condenser is discharged through the tube. The eye cannot perceive any evidence of stratifications; for the brightness of the pilot spark, together with the fluorescence both of the gas and of the glass walls effectually shield any striæ of lesser radiance which might be present. It is not possible to employ a revolving mirror. The only method which seemed to promise any results in detection of possible stratifications was the employment of a portrait lens of large aperture—four inches—in photographing single discharges. Accordingly a discharge tube was filled with hydrogen and exhausted to the striæ stage. A con-

denser of .02 m f capacity was charged to a difference of potential of 100.000 volts and discharged through the rarefied tube by flat copper bands of inappreciable self-induction. The photographs showed unmistakable striæ, superposed upon the general illumination of the tube. It is difficult to reproduce the photographs by half tones.

With an anode consisting of a ring of wire placed in a cylindrical tube .5 mm. internal diameter, a striation is formed at a short distance from the anode by condenser discharges, and there are traces of similar striations at greater distances along the tube. If these striations are formed by ionization by collision, the time of ionization is that of the duration of the pilot spark, a time which at present is beyond our power of measurement.

3. DOPPLER EFFECT.

When two anodes and two cathodes are employed in the form of tube represented in Figure 7, there are two canalstrahlen which emanate from orifices in the cathodes in opposite directions. One might suppose that the Doppler effect would be modified by collision of the particles in these rays and that the effect would certainly be less than when only one anode and one cathode were employed — the current thus passing through but one branch of the U tube. It is true that the difference of potential is less between A and D when the tube is coupled in multiple circuit than when only one branch of the tube is connected to the battery; but this difference in the case I studied was comparatively small. With both branches of the tube constituting a multiple circuit there were two strong canalstrahlen passing through the orifices in D which were undistorted and which gave the same Doppler effect which was obtained when only one branch of tube was excited; it seems difficult to reconcile this result with any theory of collision.

4. CONCLUSIONS.

1. The striæ in Geissler tubes are analogous to waves set up in narrow channels by opposing pulsations of different periods.
2. Striæ are greatly influenced by the direction of cathode rays. Certain forms of tubes, described in this article, can imitate the action of a transverse magnetic field in apparently increasing the conductivity of the rarefied gas and restoring the condition of stratification.
3. Striæ can be formed by condenser discharges; and such striæ lead one to suppose a time of ionization beyond our power of measure-

ment. By means of a suitably placed diaphragm successive stages in stratification can be produced.

4. By modification of the form of discharge tubes rectification of alternating discharges is possible.

5. The Doppler effect in hydrogen is not modified by causing two canalstrahlen to oppose each other.

JEFFERSON PHYSICAL LABORATORY, HARVARD
UNIVERSITY, CAMBRIDGE, MASS.,
December, 1909.